METHOD FOR EVALUATING THE PERFORMANCES OF A MOBILE

TELEPHONY NETWORK

DESCRIPTION

The present invention relates in a general way to the

5 field of mobile telephony and particularly to a multi-service mobile telephone network. More particularly, the present invention relates to a method for evaluating the performance of a second or third generation mobile telephone network based, for

10 example, on the CDMA standard, on the CDMA 2000 standard, on the W-CDMA standard or on the EDGE standard (evolution of the GSM/GPRS mobile telephone network).

When planning a network, designers are required to

15 predict the performance of the network on the basis of geographical data, the network configuration and the expected demand for service. Tools which simulate the operation of a network provide a practical method for planning the network. Network planning tools

20 enable designers to simulate the operation of various network configurations, and to modify the network on the basis of statistical data obtained as a result of the simulation.

The UMTS cellular network planning tools available at

25 the present time are mostly based on simulations of the static type.

US 6,111,857 describes a network planning tool in which the simulation is performed by using a set of databases containing terrain and population information

30 information associated with the market area over which the wireless network is configured. To perform

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the simulation, a composite propagation loss matrix and a demand and service vector are generated using the terrain and population information, as well as the configuration of the wireless telecommunications network. When the composite propagation loss matrix and the demand and service vector have been generated, an analysis of the reverse link is performed. Subsequently, an analysis of the forward link is performed. During both the reverse and forward link analysis the multiple iterations of analysis are performed until a stable result is achieved. Upon completion of the reverse and forward link analysis, the results of the simulation are displayed in a graphical manner for examination.

WO 03/003775 describes a wireless network planning tool which simulates wireless network operation, including subscriber admission processing, based on sophisticated reverse and forward link analyses that include data fallback procedures. Subscribers are associated with an application type, where each application type preferably has maximum and minimum data rates and one or more fallback rates. During simulation, the tool may use the fallback when evaluating forward and reverse communication links between subscribers and their associated sectors (base stations). A subscriber unable to close a reverse link to a given sector at a given data rate may be re-evaluated at a lower rate under the "fallback" procedures. Forward link analysis incorporates similar fallback procedures in forward link call admission.

Additionally, EP 1328131 A1 describes a method and a system for planning and/or evaluation of cell capacity in (CDMA) radio networks comprising at least

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one base station which defines at least one cell. The
estimate of the cell capacity in the uplink and the
estimation of the cell capacity in the downlink are
both carried out by adding an amount of traffic
5   ($T_{BS1,1}$; $T_{BS2,2}$) to the cell until a value representing
the limit capacity (L_{min}) is reached.

However, the applicant has observed that the
performance of a mobile telephone network, for
example a multi-service network, depends to a
10   significant degree on the radio resource management
(RRM) procedures and/or algorithms. This is because
the radio resource management equipment included in
the mobile telephone network require the use of a
multiplicity of RRM procedures and/or algorithms,
15   including, for example, those for admission control,
congestion control, handover control, the control
functions used when a user is in out-of-service
conditions ("outage control"), the dynamic
negotiation of the radio resource allocation, and
20   power control. Moreover, the RRM procedures and/or
algorithms may take into account the various quality
of service (QoS) requirements associated with the
services.

The applicant has also observed that another
25   fundamental aspect of the evaluation of the
performance of a mobile telephone network is the
characterization of the traffic imposed on the
network by the various services involved. The traffic
data are difficult to predict accurately, and are
30   subject to extreme variability. In a process of
planning and optimizing a mobile telephone network,
therefore, it is often necessary to evaluate the
sensitivity of the network performance as a function
of the variability of the traffic, and consequently
35   to perform numerous simulations of the network to
evaluate the impact of different traffic scenarios on

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the same network.

It is also known that there is a relationship between the simulation time and the accuracy of the simulation results. For example, in the case of a

5 certain performance parameter of the network, the accuracy with which the network simulator can estimate this parameter depends on the number of statistic samples collected, and consequently on the duration of the simulation itself. A planning and

10 optimization process may require the performance of a very large number of network simulations. Each simulation may, in turn, require the analysis of scenarios comprising a large number of users and base stations. The minimization of the simulation time is

15 therefore a necessary condition for an efficient planning and optimization process.

On the other hand, there is a risk that such minimization may be carried out at the expense of the accuracy and reliability of the results of the

20 simulations.

Dynamic simulators are generally used to evaluate the effect and/or impact of the RRM procedures and/or algorithms on the network performance and on network planning.

25 For example, WO 02/104055, in the name of the present applicant, describes a dynamic simulation system characterized by a modular structure based on interchangeable objects which can be selectively activated, and which comprise a simulation engine and

30 a plurality of modules representing the equipment and elements of the network to be simulated. This structure enables the system to simulate highly complex networks.

However, the applicant has observed that the

35 evaluation of the performance of a large network requires very long simulation times.

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Recently, another simulation method has been proposed for evaluating the performance of a UMTS network on the basis of a short-term dynamic simulation (STD simulation) method, described for example in U.
5   Türke, T. Winter, Ranjit Perera, E. Lamers, E. Meijerink, E. Fledderus and A. Serrador, "Comparison of different simulation approaches for cell performance evaluation", Deliverable D2.2, IST project MOMENTUM, October 13th 2002.

10   Short-term dynamic simulations (STD simulations) can be used to investigate the impact of mobility and the presence of different service configurations and to check that the quality of service (QoS) requirements are met. These simulations provide a larger amount of
15   data on the behaviour of the system by comparison with simulations of the purely static type, since they take into consideration important dynamic effects such as the time-dependency requirements of the bit rate of the uplink and downlink, the increase
20   and decrease of performance associated with "non real-time" data traffic, and the mobility of users.

The applicant has tackled the problem of providing a method of evaluating the performance of a mobile telephone network which can be used to simulate, with
25   adequate accuracy and reliability, the radio resource management procedures and/or algorithms, while minimizing the time required for the simulation.

The applicant has also tackled the problem of providing a method of evaluating the performance of a
30   mobile telephone network which can simulate a plurality of traffic scenarios in a single simulation, while providing adequate monitoring of the accuracy and reliability of the results.

The applicant has observed that the above problem can
35   be resolved by a method of evaluating the performance

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of a mobile telephone network, comprising at least a
first and a second simulation of a first and a second
network configuration respectively, the simulations
being statistically independent of each other (in
5 other words, neither of the two network
configurations is obtained from the other by
evolution over time). Each simulation comprises the
following steps: specifying a total number of users
to be simulated, $N_{UETOT}(s)$; determining a sequence of
10 activation of user blocks $N_{UESTEP}(s)$, included in this
total number of users to be simulated $N_{UETOT}(s)$ and
indicating a traffic distribution; activating these
user blocks in succession until the total number of
users to be simulated, $N_{UETOT}(s)$, is reached; and
15 processing at least one radio resource management
event relating to the traffic distribution associated
with each currently activated user block. The
simulations are repeated until a predetermined
threshold of accuracy is reached for each size of
20 network simulated.

More specifically, a method of evaluating the
performance of a mobile telephone network comprises
the steps of:
- simulating a first configuration of said mobile
25 telephone network;
- simulating a second configuration of said mobile
telephone network;
said first and second configurations of said mobile
telephone network being statistically independent of
30 each other;
each of said simulation steps comprising the steps
of:
- specifying a total number of users to be
simulated, $N_{UETOT}(s)$;
35 - determining a sequence of activation of user
blocks included in this total number of users to be

simulated;

- activating these user blocks in succession until said total number of users to be simulated is reached, each user block indicating a traffic 5 distribution; and

- processing at least one radio resource management event relating to the traffic distribution associated with each currently activated user block.

Another aspect of the present invention relates to 10 equipment for simulating at least a first and a second configuration of a mobile telephone network, said first and second configurations of said mobile telephone network being statistically independent of each other, and each comprising a total number of 15 users to be simulated, said simulation equipment including:

- at least one object representing a network controller belonging to said mobile telephone network; said at least one object comprising:

20　　　　- first modules for determining a sequence of activation of user blocks included in said total number of users to be simulated;

- second modules for activating said user blocks in succession until said total number of 25　　　　users to be simulated is reached, each user block indicating a traffic distribution; and

- third modules for processing at least one radio resource management event relating to the traffic distribution associated with each 30　　　　activated user block.

A further aspect of the present invention relates to a software product which can be loaded into the memory of at least one electronic computer and which comprises portions of software code for implementing 35 the procedure according to the invention when the product is executed on a computer: in this context,

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this wording is to be considered wholly equivalent to the mention of a computer-readable means comprising instructions for controlling a computer network in order to implement a procedure according to the
5   invention. The reference to "at least one electronic computer" is clearly intended to point out the possibility of implementing the solution according to the invention in a decentralized environment.

Further preferred aspects of the present invention
10   are described in the dependent claims and in the present description.

The characteristics and advantages of the present invention will be made clear by the following description of one embodiment, provided by way of
15   example and without restrictive intent, with reference to the attached drawings, in which:

-     Figure 1 shows a client-server architecture for the operation of the method of evaluating the performance of a mobile telephone network, for
20   example a multi-service network, according to the invention;

-     Figure 2 shows simulation objects used in the evaluation method according to the invention;

-     Figures 3 and 4 show data structures used in the
25   evaluation method according to the invention; and

-     Figures 5 and 6 show flow diagrams relating to the evaluation method according to the invention.

With reference to Figure 1, the method for evaluating the performance of a mobile telephone network
30   according to the invention can operate by means of a client-server architecture 1, of a known type,

described below. By way of example and without
restrictive intent, the multi-service mobile
telephone network to which reference will be made in
the rest of the present description is a third

5   generation multi-service network with radio access of
the WCDMA type, compatible with the UMTS standard.
However, the evaluation method according to the
invention is also applicable to second or third
generation networks based, for example, on the CDMA

10 2000 standard or on the EDGE standard (evolution of
the GSM/GPRS network).

Also with reference to Figure 1, the client-server
architecture 1 comprises: a client computer 2, for
example a personal computer, in which a graphic

15 interface program 3 of a known type is installed; a
server computer 4, for example a Work Station, in
which is installed a simulator 5 of the static type,
for evaluating the performance of the multi-service
mobile telephone network to be examined.

20 Specifically, the simulator 5 receives at its input:

-   a configuration file 6 comprising a set of
network configuration parameters, listed below in the
present description, which describe the
characteristics of the multi-service mobile telephone

25 network. The network configuration parameters are
defined by the mobile telephone operator, using the
graphic interface program 3;

-   a structured set of terrain data, listed below
in the present description, and retrieved from a

30 terrain database 7;

-   a set of statistical data, listed below in the

present description, which describe the performance of the multi-service mobile telephone network. These statistical data are then stored, in a structured way, in a database of the simulation data 8, and are
5 subsequently sent to the graphic interface program 3 which displays them.

As shown in Figure 1, the client computer 2 and the server computer 4 are interconnected by a data network 9, of a known type, based for example on a
10 TCP/IP protocol. Alternatively, the client computer 2 and the server computer 4 can be combined in a single computer.

The network configuration parameters included in the configuration file 6 can include, for example,

15 -   the number of cells making up the multi-service mobile telephone network;

-       the geographical positions of said cells;

-       the number of transceiver stations (nodes B according to the UMTS standard) present in the
20 network;

-       the identification of the cells associated with each node B;

-       the characteristics of each node B, such as the antenna gain, the radiation pattern, the direction of
25 maximum radiation (defined in terms of azimuth and tilt), the noise figure of the receiver, the antenna connection losses and the transmission powers of the common channels;

-       the characteristics of the mobile terminals to
30 be simulated, such as the noise figure of the

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receiver incorporated in each mobile terminal, the gain and losses associated with the terminal antenna, the maximum transmission power available for the uplink, and the power dynamics of the mobile
5 terminal;

- the characteristics of the various services supported by the network, such as the class of service (which indicates in a summary way the quality requirements associated with the service); the set of
10 transport formats associated with the service; the set of activity factors which describe in statistical terms the behavior of the mobile terminal using the service;

- the control parameters for the radio resource
15 management procedures and/or algorithms (RRM algorithms), comprising, for example, the thresholds of macrodiversity, in other words the capacity for maintaining the current call between a mobile terminal and the mobile telephone network via more
20 than one transceiver station; the admission control thresholds, in other words the thresholds beyond which a mobile terminal requiring a given service cannot be admitted into the network; and the congestion control thresholds, in other words the
25 thresholds beyond which conditions of "overload" occur, these being conditions in which the network is not capable of meeting the requirements of the connected mobile terminals while maintaining the quality requirements associated with the various
30 services.

It should be made clear that the time variable is not taken into account in the static simulations, but the

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network is analyzed in a particular situation, as if
by taking a snapshot. By conducting a plurality of
analyses (taking a plurality of "snapshots") of the
network in different situations, it is possible to
5 obtain a global evaluation of the network.
Consequently, the static simulation according to the
invention does not generally include radio resource
management parameters which represent "times" (where
time is considered to be an independent variable),
10 for example the radio protocol timers and the
temporal hysteresis.

Furthermore, the terrain data stored in the terrain
database 7 and associated with the area over which
the multi-service mobile telephone network is
15 configured can comprise, for example,

-    a traffic matrix of a known type, whose elements
indicate the expected traffic for each terrain
element (pixel) making up a single cell, and for each
service supplied by the multi-service mobile
20 telephone network, defined for example on the basis
of one of the approaches described in WO/35872;

-    an altitude matrix, of a known type, whose
elements indicate the mean attitude above sea level
of each terrain element;

25 -   a morphology matrix of a known type, whose
elements indicate the morphology of each terrain
element; and

-    a building matrix of a known type, whose
elements indicate the percentage of building present
30 in each terrain element..

Additionally, the statistical data obtained at the

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output of the simulator 5 and stored in the database of the simulation data 8 can comprise, for example,

-    the total received wideband power for each cell, defined for example according to the 3GPP 25.115
5   specification;

-    a noise factor (NR) associated with each cell and defined by the following known expression:

$$NR = \frac{RTWP}{NF \cdot W \cdot kT}$$

where RTWP denotes the total power received over the
10 uplink by the cell; NF denotes the noise figure at the receiver of the cell; W is the bandwidth of the WCDMA relative to the cell, and kT is the power spectral density of the thermal noise;

-    the load factor for the uplink associated with
15 each cell and calculated according to the following known expression:

$$\eta = 1 - \frac{1}{NR}$$

-    the estimated noise factor found for the uplink from the number of links associated with each cell,
20 calculated on the basis of the following known expression:

$$\overline{\eta_{UL}} = \sum_{s=1}^{Nserv} N(s) \cdot \chi_{UL}(s)$$

where N(s) denotes the number of active links associated with the cell for the service s, N_{serv}
25 denotes the number of services and $\chi_{UL}(s)$ denotes the load associated with the individual link, estimated for the uplink, for example, by means of the

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expressions published in Holma, Toskala, "WCDMA for UMTS", Wiley, 2001;

- the total power transmitted by each cell, defined for example according to the 3GPP 25.115 5 specification;

- the power transmitted by each cell in each traffic channel, defined for example according to the 3GPP 25.115 specification;

- the percentage of mobile terminals out of 10 service for each terrain element;

- the total number of "spreading" codes required for each cell, calculated, for example, by considering the value of the "spreading factor" parameter which characterizes each transport format, 15 according to the orthogonal variable spreading factor (OVSF) method described in the 3GPP 25.213 specification;

- the estimated load factor found for the downlink from the number of links associated with each cell, 20 calculated on the basis of the following known expression:

$$\overline{\eta_{DL}} = \sum_{s=1}^{Nserv} N(s) \cdot \chi_{DL}(s)$$

where $N(s)$ denotes the number of active links associated with the cell for the service s, N_{serv} 25 denotes the number of services and $\chi_{DL}(s)$ denotes the load associated with the individual link, estimated for the downlink, for example, by means of the expressions published in Holma, Toskala, "WCDMA for UMTS", Wiley, 2001.

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With reference to Figure 2, the simulator 5, developed for example in C++ programming language by means of a design platform of the UML ("Unified Modelling Language) type, comprises, in what is known

5 as an object-oriented approach:

-    a simulation engine 10, comprising modules, described below, for managing and developing the simulation;

-    an object of the RNC_MC type, indicated by

10 reference number 11, comprising modules, described more fully in the following part of the present description, which simulate the behaviour of a radio network controller. In a mobile telephone network, the network controllers manage the radio resources

15 and control the radio transport;

-    a plurality of objects of the UE_MC type, indicated by reference number 12, each comprising modules, described below, which simulate the behaviour of a mobile terminal. Each UE_MC object is

20 also associated with a reference service belonging to a service class selected, for example, from those listed in the 3GPP specifications and indicated by the terms "Conversational", "Streaming", "Interactive", and "Best Effort";

25 -   a plurality of objects of the Node B_MC type, indicated by reference number 13, each comprising modules, described below, which simulate the behavior of a transceiver station (node B) and of the UMTS cells associated with it. This is because each node B

30 can supervise a variable number of UMTS cells, each of which is associated with a transmitter and a

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receiver;

- an object of the PROP ("Propagation Module") type, indicated by reference number 14 and described in detail in the following part of the present

5 description;

- an object of the RLM ("Radio Link Monitor") type, indicated by reference number 15 and described in detail in the following part of the present description.

10 In the object-oriented approach, the elementary unit of analysis is not an operation (procedure) but an object, in the sense of an aggregation of variables, data structures and procedures, considered as a single entity in the context of the simulator. In the

15 present case, the simulation objects are generally models of real entities (objects in the real world).

In greater detail, the simulation engine 10 comprises the following modules, not shown in Figure 2:

- a first module, implemented for example in a

20 similar way to the "Parameters manager" module described in WO 02/104055, which reads and interprets the network configuration parameters contained in the configuration file 6 and makes this information available for the creation of the simulation objects

25 in the initialization step of the simulation;

- a second module, implemented for example in a similar way to the "Factory Manager" module described in WO 02/104055, which optimizes the memory allocation of the simulation objects;

30 - a third module acting as an event scheduler,

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implemented for example in a similar way to the
"Event Scheduler" module described in WO 02/104055,
which establishes the sequence of execution of the
simulation steps and, more particularly, the sequence
5 in which the radio resource management events are
processed; at least one radio resource management
procedure and/or algorithm being implemented in each
radio resource management event;

- a fourth module, implemented for example in a
10 similar way to the "Statistic Manager" module
described in WO 02/104055, which manages modules for
collecting and processing the simulation results.

Additionally, the PROP object 14 comprises a module
which determines a set of attenuation values (one for
15 each cell of the network under examination) for each
terrain element included in the mobile telephone
network under examination. The attenuation is
calculated from the terrain data by combining a
deterministic component and a statistical component.
20 The deterministic component can be calculated, for
example, by the known method of Okumura Hata
described in M. Hata, "Empirical Formula for
Propagation Loss in Land Mobile Radio Services", IEEE
Transactions on Vehicular Technologies, 1980, while
25 the statistical component can be calculated by using
a pseudo-random number generator of a known type,
based for example on the method described in G.
Marsaglia, K. Ananthanarayanan and N. Paul, Random
Number Generator Package - 'Super Duper', School of
30 Computer Science, McGill University, Montreal,
Canada, 1973. In this case, the statistical component
is simulated as a random variable having lognormal

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distribution, as specified in the document ETSI 30.03.

The RLM object 15 comprises a module which calculates the interference levels, and consequently the signal/noise ratios for each link. Specifically, a link is an association between one of the receivers present in the mobile telephone network under examination and belonging to a UE_MC object 12 or a NodeB_MC object 13, and one of the transmitters, also belonging to a UE_MC object 12 or a NodeB_MC object 13. In particular, an "uplink" is a link between a transmitter associated with a mobile terminal and a receiver associated with a cell belonging to a Node B, while a "downlink" is a link between a transmitter associated with a cell belonging to a Node B and a receiver associated with a mobile terminal.

Additionally, the principle of macrodiversity, specified by the UMTS standard, requires that, for an uplink, it should be possible to associate a single transmitter at the mobile terminal with a plurality of receivers belonging to different cells and possibly to different Nodes B. The principle of macrodiversity also requires that, for a downlink, it should be possible to associate a receiver at the mobile terminal with a plurality of transmitters belonging to different cells and, possibly, to different Nodes B. The transmitter-receiver associations are determined in the initial steps of the simulation by macrodiversity management algorithms, as stated in the 3GPP document 25.922.

In detail, for each transmitter-receiver link, the RLM object 15 determines the useful signal C_i

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according to the following known expression:

$$C_i = P_i \cdot A_{i,i}^s$$

where P_i denotes the power transmitted by the transmitter associated with the receiver in question,

5   while $A_{i,i}$ denotes the attenuation associated with the transmitter-receiver link and calculated from the PROP object 14 on the basis of the terrain element in which the mobile terminal in question is located.

·The interference is calculated according to the

10 following known expression: ·

$$I_i = \sum_{j \ne i} P_j \cdot A_{i,j} \cdot ACIR_{i,j}$$

where the summation is extended to all the transmitters except that associated with the receiver in question, these transmitters being called

15 interferers. P_j denotes the power of the single interferer, $A_{i,j}$ denotes the attenuation associated with the link between the receiver i in question and the interferer j, and $ACIR_{i,j}$ denotes the additional attenuation present in the case in which the receiver

20 i and the transmitter j operate at different frequencies. The additional attenuation $ACIR_{i,j}$ is calculated from the following known expression:

$$ACIR_{i,j}\left(f_i, f_j\right) = \frac{1}{\left(ACS_i\left(f_i, f_j\right)\right)^{-1} + \left(ACLR_j\left(f_i, f_j\right)\right)^{-1}}$$

where ACS_i and $ACLR_j$ denote, respectively, the

25 "adjacent channel selectivity" parameter and the "adjacent channel loss ratio" parameter. These two parameters are defined according to the characteristics of the receiver i and the transmitter

j as a function of the frequencies f_i and f_j associated with them, according to the definitions in the 3GPP document 25.942.

The signal/noise ratio associated with the link i is
5 calculated by using the following known expression:

$$SNR_i = \frac{C_i}{I_i + NF \cdot W \cdot kT}$$

where NF is the noise figure of the receiver of the cell, W is the bandwidth of the WCDMA channel for the cell, and kT is the power spectral density of the
10 thermal noise. Additionally, in the presence of macrodiversity, the calculation of the signal/noise ratio is modified to allow for the effect of signal recombination associated with the different links. In accordance with the UMTS standard, this recombination
15 is simulated in different ways for the uplink and the downlink.

In detail, in the case of the downlink, the following known expression is used to determine the total signal/noise ratio from the signal/noise ratios of
20 the individual links:

$$\left.\frac{C}{I}\right|_{TOT} = \sum_i \frac{C_i}{I_i}$$

where the summation is extended to the set of links in macrodiversity mode;

In the case of the uplink, however, it is necessary to distinguish between the conditions of:

25 to distinguish between the conditions of:

-    softer handover: the mobile terminal is in macrodiversity mode and is located in an area of overlap between cells associated with the same Node

B. The recombination model is similar to that described for the downlink.

- soft handover: the mobile terminal is in macrodiversity mode and is located in an area of

5 overlap between cells associated with different Nodes B. The signals associated with the different links are recombined by the network controller (RNC) which selects the link which provides the best quality in terms of BLER (BLock Error Rate). In the simulation,

10 the RLM object 15 calculates a signal/noise ratio for each of the links in macrodiversity mode, leaving the RNC_MC object 11 to carry out the recombination.

Again with reference to Figure 2, according to the invention, the UE_MC objects 12 comprise:

15 - a first module UE_RRC_MC 16 which simulates the functions of the RRC ("Radio Resource Control") protocol level of the UMTS mobile telephone network and the subset of radio resource management functions to be provided by the mobile terminal (described more

20 fully in the following part of the present description);

- a second module UE_PHY 17 which simulates the first protocol level or physical level of the mobile terminal, and comprises a plurality of objects of the

25 transmitter type 18 and receiver type 19, according to the UMTS standard.

Specifically, the principal operations executed by the first UE_RRC_MC module 16 can be summarized as follows:

30 - configuration of the parameters associated with the first protocol level or physical level of the

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UMTS mobile telephone network according to the characteristics of the service associated with the mobile terminal;

- interfacing with a first module NodeB_RRC_MC 20,
5 incorporated in the NodeB_MC object 13 and described below, for implementing the power control procedures specified by the UMTS standard;

- interfacing with the RNC_MC object 11 for implementing the RRM procedures and/or algorithms
10 associated with the various radio resource management events.

According to the invention, the NodeB_MC objects 13 comprise:

- the first module, NodeB_RRC_MC 20, which
15 simulates the functions of the RRC ("Radio Resource Control") protocol level of the UMTS mobile telephone network and the subset of the radio resource management functions to be provided by the Node B (described more fully in the following part of the
20 present description);

- a second module, NodeB_PHY 21, which simulates the physical level of the Node B and comprises a plurality of objects of the cell type 22. Each object of the cell type 22 comprises a plurality of objects
25 of the transmitter type 23 and receiver type 24, according to the UMTS standard.

Specifically, the principal operations executed by the first NodeB_RRC_MC module 20 can be summarized as follows:

30 - configuration of the common channels (according

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to the UMTS standard) for the cells controlled by each Node B;

- interfacing with the first module UE_RRC_MC 16 for implementing the power control procedures
5 specified by the UMTS standard;

- interfacing with the RNC_MC object 11 for implementing the RRM procedures and/or algorithms associated with the various radio resource management events.

10 As shown in Figure 3, according to the invention, the RNC_MC object 11 comprises data structures which support the radio resource management operations.

Specifically, the RNC_MC object 11 includes:

- a list of activatable mobile terminals 25,
15 structured by service class and by service;

- a list of active mobile terminals 60, structured by service class and by service in a way which is entirely similar to that described for the list of mobile terminals to be activated 25; and therefore
20 not shown in detail in Figure 3; and

- a set 26 of lists of mobile terminals out of service, one for each cause of outage.

- a map of the system resources 30.

As shown in Figure 3, the list of mobile terminals to
25 be activated 25 can, for example, comprise twelve references to UE_MC objects 12, indicated respectively as $UE*_{1-12}$, and can be structured in three service classes and four services; in particular,

30 -   the references $UE*_1$, $UE*_7$, $UE*_{12}$ correspond to

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mobile terminals associated with a first service, indicated by the reference number 31a, which belongs for example to the "Conversational" service class, indicated by the reference number 31;

5   -   the references UE*$_6$, UE*$_2$, UE*$_{11}$ correspond to mobile terminals associated with a second service, indicated by the reference number 31b, which belongs for example to the "Conversational" service class 31;

-      the references UE*$_3$, UE*$_4$, UE*$_{10}$ correspond to 10 mobile terminals associated with a service, indicated by the reference number 32a, which belongs for example to the "Interactive" service class, indicated by the reference number 32;

-      the references UE*$_9$, UE*$_5$, UE*$_8$ correspond to 15 mobile terminals associated with a service, indicated by the reference number 33a, which belongs for example to the "Background" service class 33.

Again with reference to Figure 3, the set 26 can comprise, for example, three lists of references to 20 mobile terminals which are out of service, indicated by the reference numbers 27, 28 and 29 respectively. Each of the lists of mobile terminals out of service 27, 28 and 29 is structured by service class and by service in a wholly similar way to that described for 25 the list of mobile terminals to be activated 25.

In the example shown in Figure 3, the lists of mobile terminals out of service 27, 28 and 29 can be associated with three different causes of outage, indicated by A, B and C respectively. In particular, 30 the list of mobile terminals out of service 27 can correspond to cause A, the   list of mobile terminals

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out of service 28 can correspond to cause B, and the list of mobile terminals out of service 29 can correspond to cause C.

There may be multiple causes of outage. They are
5 detected by the radio resource management procedures and/or algorithms. For example, a mobile terminal may be out of service because of lack of coverage, or because of the admission control procedures and/or algorithms, or the congestion control procedures
10 and/or algorithms or the outage control procedures and/or algorithms.

Additionally, the map of the system resources 30, according to the invention, comprises a plurality of structures, each corresponding to a node B of the
15 network under examination. Each structure comprises a reference to a Node B and a list of objects of the Cell Context type, one for each cell controlled by the Node B.

In particular, in the example shown in Figure 3, the
20 map of system resources 30 comprises three structures indicated by the reference numbers 30a, 30b and 30c respectively and corresponding to three objects of the NodeB_MC type 13 respectively. In greater detail, the structure 30a comprises a reference $30a_1$ to the
25 Node B_1 and a list of Cell Context objects $30a_2$ associated with the cells controlled by the Node B_1; the structure 30b comprises a reference $30b_1$ to the Node B_2 and a list of Cell Context objects $30b_2$ associated with the cells controlled by the Node B_2;
30 the structure 30c comprises a reference $30c_1$ to the Node B_2 and a list of Cell Context objects $30c_2$ associated with the cells controlled by the Node B_3.

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Figure 4 shows an example of a list of Cell Context objects.

As shown in Figure 4, each list of Cell Context objects, for example the list $30a_2$ comprises a

5   pointer 40 to the list and three Cell Context (41, 42, 43) corresponding to three cells controlled by a single Node B.

Each Cell Context object, for example the Cell Context object 41, comprises:

10 -   a cell identification code 44 (Cell ID);

-   frequency identifiers 45 for the frequencies used by the cell for transmission (downlink) and reception (uplink);

-   a list of references to mobile terminals 46,

15 comprising mobile terminals which are operating in macrodiversity mode with the cell. The list of references to mobile terminals 46 is structured by service class and by service, in a way wholly similar to that specified for the list of mobile terminals to

20 be activated 25;

-   a list of blocked links 47, comprising an indication of the links of the cell which have been blocked and an indication of the cause of blocking for each blocked link;

25 -   a first set of parameters 48 relating to the radio resource management in the uplink. For example, the first set of parameters 48 can comprise the following known parameters: the load threshold for the admission control (differentiated by service or

30 by class of service if required); the load threshold

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for the admission control relating to mobile
terminals in macrodiversity mode (differentiated by
service or by class of service if required); the load
threshold for the congestion control (differentiated
5 by service or by class of service if required); the
terminal power threshold for the outage control and
the signal/noise ratio threshold for the outage
control;

-    a second set of parameters 49 relating to the
10 radio resource management in the downlink. For
example, this second set of parameters 49 can
comprise the following known parameters: the load
threshold for the admission control (differentiated
by service or by class of service if required); the
15 load threshold for the admission control relating to
mobile terminals in macrodiversity mode
(differentiated by service or by class of service if
required); the load threshold for the congestion
control (differentiated by service or by class of
20 service if required); the maximum number of codes
that can be allocated; the power threshold for the
admission control, differentiated by service or by
class of service if required; the power threshold for
the admission control relating to mobile terminals in
25 macrodiversity mode (differentiated by service or by
class of service if required) and the power threshold
for the congestion control (differentiated by service
or by class of service if required);

-    a third set of parameters 50 relating to the
30 load indicators of the uplink. For example, the third
set of parameters 50 can comprise the following known
parameters: the uplink load, calculated from the

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number of links of the cell; the downlink load, calculated from the noise rise factor;

- a fourth set of parameters 51 relating to the load indicators of the downlink. For example, this
5 fourth set of parameters 51 can comprise the following known parameters: the downlink load, calculated from the number of links of the cell; the total number of codes allocated; and the total power transmitted in the downlink.

10 Additionally, Figure 4 shows an example of a list of blocked links 47 relating to one cell with, for example, two blocked links corresponding to two separate mobile terminals.

In the example shown in Figure 4, the list of blocked
15 links 47 comprises a pointer 52, a first object 53 comprising information on the first blocked link and a second object 54 which comprises information on the second blocked link.

Specifically, the first object 53 comprises a
20 reference 55 to a first blocked mobile terminal and a code 56 indicating the cause of blocking of the link, while the second object 54 comprises a reference 57 to a second blocked mobile terminal and a code 58 indicating the cause of blocking of the link.

25 It should be pointed out that possible causes of blocking of a link may be:

- poor reception quality of the pilot channel;

- poor reception quality of the synchronization channel;

30 - blocking by the admission control procedures

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based on the maximum number of links per cell;

- blocking by the admission control procedures based on the maximum load factor per cell in the uplink;

5 - blocking by the admission control procedures based on the maximum transmitted power per cell in the downlink;

- blocking by the admission control procedures based on the maximum number of codes allocated per 10 cell in the downlink;

- blocking by the load control procedures based on the maximum load factor per cell in the uplink;

- blocking by the load control procedures based on the maximum power transmitted per cell in the 15 downlink;

- outage blocking based on the control of the maximum available power associated with the mobile terminal;

- outage blocking based on the control of the 20 minimum signal/noise ratio in the uplink;

- outage blocking based on the control of the minimum signal/noise ratio in the downlink.

The method according to the invention will now be described with reference to the flow diagram shown in 25 Figure 5. In detail, the flow diagram of Figure 5 represents a simulation algorithm 100 which operates according to the invention.

It should be noted that the development of the simulation algorithm 100 depends on the simulation 30 engine 10 which controls the sequences of simulation

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steps which make up the algorithm.

Additionally, during each simulation step, each simulation object participates in the determination of the development of the simulation by interacting

5   directly with the other objects, by sending information elements called "messages".

Specifically, the message communication system is characterized in that the reception of the information by the target object takes place

10 simultaneously with the sending by the source object.

In detail, the simulation algorithm 100, according to the invention, comprises a step of initialization of the simulation 101 and one or more iterative steps of event-based micro-simulation 102.

15 In each step of event-based micro-simulation 102 a network configuration is simulated, and all the network configurations simulated in the course of the simulation are statistically independent of each other.

20 In the following part of the present description and claims, the term "statistically independent" denotes that neither of two network configurations simulated in two successive event-based micro-simulations is the temporal evolution of the other.

25 Additionally, the analysis of one or more traffic distributions is provided in each step of event-based micro-simulation 102. Each step of event-based micro-simulation 102 also comprises one or more iterative steps of processing radio resource management events.

30 In particular, the radio resource management (RRM)

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comprises the set of procedures and/or algorithms for managing the radio resources. The RRM procedures comprise, for example, handover control, power control, admission control, congestion control,
5 outage control, etc.

More specifically, the handover procedure is necessary for the management of the mobility of users when they move from the coverage area of one cell to another. Power control is required for minimizing the
10 interference level on the radio interface and for ensuring the quality of the requested service. Admission control is required for verifying that the acceptance of a new link does not cause a reduction in the planned coverage area for a single cell, or a
15 reduction of the quality of existing links. Congestion control is required for detecting an overload condition and subsequently returning the network to the load value which was specified when the network was planned.

20 For example, for a multi-service mobile telephone network based on the UMTS standard, the RRM procedures and/or algorithms are implemented in the RRC (Radio Resource Control) network level of the radio access network (UTRAN: UMTS Radio Access
25 Network). This level has the function of supervising and coordinating the functionality present in the other network levels (MAC: Medium Access Control, RLC: Radio Link Control, and the physical level), for correct and efficient use of the channels made
30 available by the physical level.

In detail, the step of initialization of the simulation 101 comprises the following steps executed

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by the simulation engine 10:

- reading the parameters in the configuration file 6;

- creating the simulation objects on the basis of
5 the network configuration parameters read from the
configuration file 6. More specifically, the
simulation engine 10 generates the NodeB_MC objects
13, the RNC_MC objects 11, the RLM objects 15, the
PROP objects 14 and the UE_MC objects 12. These
10 objects are divided into subsets corresponding to the
different values of network configuration parameters
associated with them.

In particular, different subsets can correspond, for
example, to different services, or to different
15 propagation conditions. For example, it is possible
to simulate the presence in the network under
examination of mobile terminals requiring different
services, and, for each service, to simulate the
presence of mobile terminals located inside
20 buildings, in other words mobile terminals
characterized by additional attenuation not specified
by the PROP object 14 and due to the buildings
themselves.

The configuration file 6 specifies, for each service,
25 the possible transport formats to be used and the
characteristic parameters of each transport format,
for both the uplink and the downlink.

By way of example and without restrictive intent, we
may cite the following characteristic parameters of
30 the transport format relating to the uplink:

- the transmission bit rate;

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- the target signal/noise ratio;

- the parameters determining the distribution of the transmitted power between the physical data channel, which carries the user information, and the

5 physical transport channel; and

- the load estimate associated with each uplink used in the admission control step.

The transport formats for the uplink are stored in a list in order of decreasing bit rate, associated with

10 each UE_MC module 12 and defined in the configuration file 6.

By way of example and without restrictive intent, we may cite the following characteristic parameters of the transport format relating to the downlink:

15 -   the transmission bit rate;

- : the target signal/noise ratio;

- - the spreading factor which determines the number of codes allocated over the serving cells;

-    the parameters determining the distribution of

20 the transmitted power between the physical data channel, which carries the user information, and the physical transport channel; and

-    the power estimate associated with each downlink used in the admission control step.

25 The transport formats for the downlink are stored in a list in order of decreasing bit rate, associated with each UE_MC module 12 and defined in the configuration file 6.

The step of initialization of the simulation 101 also

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comprises the following steps executed by the PROP
object 14 and by the NodeB_MC object 13 respectively:

- calculation of the propagation data, using the
information retrieved from the terrain database 7;
5 the deterministic component of the attenuation
associated with each cell present in the mobile
telephone network under examination is calculated for
each terrain element;

- configuration of the common channels for the
10 cells controlled by the NodeB_MC object 13; a
transmitted power value, determined according to the
configuration file 6, is specified for each cell and
for each channel; the minimum set of common channels
used comprises the pilot channel CPICH (Common PIlot
15 CHannel), the synchronization channel SCH
(Synchronization CHannel), and the primary control
channel P-CCPCH (Primary Common Control Physical
CHannel).

Still with reference to Figure 5, each step of event-
20 based micro-simulation 102 comprises an
initialization step 102a including the following
steps:

- Updating of the propagation data by the PROP
object 14. In detail, the PROP object 14 calculates
25 the statistical component of the attenuation
associated with each cell present in the mobile
telephone network under examination for each terrain
element. The PROP object 14 then adds this
statistical component, expressed in logarithmic
30 units, to the deterministic component (also expressed
in logarithmic units) which it calculated previously

in the step of initialization of the simulation 101;

- Calculation of its own position by each UE_MC object 12. In detail, each UE_MC object 12 calculates its own position within the simulation scenario, this
5. position being used for the whole current event-based micro-simulation. The position determination consists in the selection of one of the terrain elements belonging to the geographical area under examination, carried out on the basis of the predicted traffic
10 distribution for a given service S associated with the UE_MC object 12 in question. Specifically, each terrain element (m, n) is associated with a selection probability $Pr_s(m,n)$ which, according to the invention, is defined, for the service S, by the
15 following expression:

$$Pr_s(m,n) = \frac{t_s(m,n)}{T_s}$$

where the term $t_s(m,n)$ denotes the value of the traffic for the terrain element (m,n) supplied by the traffic matrix for the service S, while the term T_s
20 denotes the sum of all the traffic matrix elements of the service S associated with the terrain elements belonging to the area under examination. The traffic matrices associated with the different services are contained in the terrain data database 7 described
25 previously. Each UE_MC object 12 also selects the initial transport format, for both the uplink and the downlink, from the available transport formats provided in the configuration file 6;

- initialization of the data structures used for
30 simulating the radio resource management, carried out

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by the RNC_MC object 11. In detail, the RNC_MC object 11 sets the number of active links for each cell to 0, sets the current value of the load factor for each cell to 0, sets the power transmitted by each cell to

5   a value obtained by adding together the powers associated with the common channels, and sets the number of codes allocated for each cell to a value obtained by adding together the number of codes allocated to the common channels only;

10   -   execution by each UE_MC object 12 of a set of procedures for simulating the power measurements in the common channels carried out by the mobile terminals in the UMTS system. In detail, the UE_MC object 12 obtains from the RLM module 15 the value of

15   power received on the pilot channel CPICH associated with each cell in the mobile telephone network for which a calculated attenuation value exists in relation to the terrain element in which the UE_MC object 12 is located. On the basis of comparative

20   measurements, the UE_MC object 12 determines its own "best CPICH" cell. The "best CPICH" cell of each UE_MC object 12 is the cell with which is associated the highest power value in respect of the reception of the pilot channel CPICH. Specifically, if

25   $CPICH\_RSCP_j$ denotes the power received on the pilot channel by a cell j, the UE_MC object 12 determines its own best CPICH cell by using the following known relation:

$$CPICH\_RSCP_k \geq CPICH\_RSCP_j$$

30   where k is the best CPICH cell, while j varies in such a way as to allow for the set of power

measurements made by the UE_MC object 12. The UE_MC object 12 also carries out a check of a known type on the minimum power level $CPICH\_RSCP_k$ associated with the best CPICH cell. If the following relation is

5 true:

$$CPICH\_RSCP_k \geq Slev\_CPICH$$

the reference to the UE_MC object 12 in question is added to the list of mobile terminals to be activated 25; otherwise the reference to the UE_MC object 12 in

10 question is added to the list of mobile terminals out of service 26, with the note "no coverage". Slev_CPICH is a characteristic parameter of the UE_MC object 12 and is defined in the configuration file 6.

The UE_MC object 12 also determines its own

15 "candidate set", in other words the set of candidate cells for macrodiversity, on the basis of the measures made. This set consists of cell k (best CPICH cell) and all cells for which the following known expression is true:

20 $$CPICH\_RSCP_j \geq CPICH\_RSCP_k - \Delta_{SH}$$

where $CPICH\_RSCP_j$ denotes the power received by the UE_MC object 12 in question at the cell j (expressed in logarithmic units); $RSCP_k$ denotes the power received by the UE_MC object 12 in question at the

25 best CPICH cell (expressed in logarithmic units); and Δ_{SH} is a radio resource management parameter, called the macrodiversity window.

The step of initialization 102a of the event-based micro-simulation also comprises a step of positioning

30 a radio resource management event controlled by the

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simulation engine 10 in the list of events. This event will subsequently be processed by the RNC_MC object 11.

Each step of event-based micro-simulation 102 can 5 comprise one or more iterative steps of processing radio resource management events, whose sequence is determined by the event scheduler module incorporated in the simulation engine 10. For example, each step of event-based micro-simulation 102 can comprise (see 10 Figure 5):

-    a step of processing an admission control event 103, carried out by the RNC_MC object 11. This admission control event comprises the activation, controlled by the admission control procedures and/or 15 algorithms, of a set of UE_MC objects 12 which simulate the mobile terminals present in the network (the criteria for determining this group of UE_MC objects will be described subsequently);

-    a first step of processing a power control event 20 104, carried out by the NodeB_MC objects 13 and by the UE_MC objects 12 active in step 104;

-    a first step of checking the power convergence condition 105, carried out by the RNC_MC object 11.

If the first step of checking the power convergence 25 condition 105 has a negative outcome, the simulation engine 10 causes the first step 104 to be executed. Conversely, if the first step of checking the power convergence condition 105 has a positive outcome, the simulation engine 10 causes the execution of:

30 -   a step of processing a congestion control event 106 carried out by the RNC_MC object 11. During this

congestion control event, a subset of active mobile terminals may be taken out of service according to the congestion control procedures and/or algorithms;

- a second step of processing a power control

5 event 107, carried out by the NodeB_MC objects 13 and by the UE_MC objects 12 active in step 106;

- a second step of checking the power convergence condition 108, carried out by the RNC_MC object 11.

If the second step of checking the power convergence

10 condition 108 has a negative outcome, the simulation engine 10 causes the second step 107 to be executed. Conversely, if the second step of checking the power convergence condition 108 has a positive outcome, the simulation engine 10 causes the execution of:

15 - a step of processing an outage control event 109, carried out by the RNC_MC object 11. During this step 109, a subset of active mobile terminals may be taken out of service according to the outage control procedures and/or algorithms;

20 - a third step of processing a power control event 110, carried out by the NodeB_MC objects 13 and by the UE_MC objects 12 active in step 109;

- a third step of checking the power convergence condition 111, carried out by the RNC_MC object 11.

25 If the third step of checking the power convergence condition 111 has a negative outcome, the simulation engine 10 causes the third step 110 to be executed. Conversely, if the third step of checking the power convergence condition 111 has a positive outcome, the

30 simulation engine 10 causes the execution of:

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- a step of collecting and processing the statistical results 112, which produces at the output a set of statistical results 113, stored in the simulation database 8;

5   -   a step of checking the attainment of a total number of users to be activated 115. This number corresponds to the total number of users to be activated $N_{UETOT}(s)$ in the course of the simulation for each service s. Specifically, this number is

10   contained in the configuration file 6 and can, for example, be calculated from the traffic matrices associated with each service provided by the mobile telephone network and stored in the terrain database 7.

15   If the step of checking the attainment of a final configuration of users 115 has a negative outcome, the simulation engine 10 causes the execution of the first step 103, which activates one or more mobile terminals in sequence (providing a new traffic

20   distribution), these terminals being added to the number of already active mobile terminals. Conversely, if the step of checking the attainment of a final configuration of users 115 has a positive outcome, the simulation engine 10 causes the

25   execution of:

-   , a step of checking the accuracy of the statistical data obtained, 116.

If the step of checking the accuracy of the statistical data obtained 116 has a positive outcome,

30   the simulation engine 10 terminates the simulation algorithm 100 (stop); otherwise the simulation engine

10 causes the execution of a new step of event-based micro-simulation 102.

In detail, in the step of processing an admission control event 103, the RNC_MC object 11 carries out 5 the following operations:

- it determines the number of UE_MC objects 12 to be activated for each service according to the current network conditions. The current network conditions are described by the system resources map 10 30 and by the set of radio resource management parameters 48, 49. In particular, according to the invention, the RNC_MC object 11 uses the following procedure to calculate the number of UE_MC objects 12 to be activated:

15 1) it determines the number of mobile terminals already activated in preceding admission control events, in the course of the current micro-simulation. For each service, this number corresponds to the sum of the number of mobile terminals in 20 service $N_{UESERV}(s)$ and the number of mobile terminals out of service $N_{UEOUT}(s)$;

2) it extracts from the configuration file 6, for each service, a minimum number $N_{UEMIN}(s)$ and a maximum number $N_{UEMAX}(s)$ of users, by means of which it is 25 possible to, set, respectively, a maximum and a minimum limit for the set of UE_MC objects 12 associated with the service s to be activated, during the single admission control event;

3) it extracts from the configuration file 6 the 30 total number of users to be activated $N_{UETOT}(s)$.

In particular, the total number of users to be

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activated $N_{UETOT}(s)$ in the course of the simulation can be calculated, for example, by using the following expression:

$$N_{UETOT}(s) = \gamma(s) \cdot T_s$$

5   where T_s represents the sum of all the elements of the traffic matrix associated with this service, while $\gamma(s)$ is a network configuration parameter contained in the configuration file 6, used for determining the total traffic generated in the course

10   of the simulation, with the application of a multiplication factor to the reference traffic associated with the terrain database 7;

4)   for each cell j, it extracts from the corresponding list of Cell Context objects the

15   current value $\eta(j)$ of the load factor of the uplink and the admission control threshold $\eta_{lim}(j)$ for this link;

5)   for each cell j, it extracts from the corresponding list of Cell Context objects the

20   current value $P(j)$ of the power transmitted in the downlink and the power threshold $P_{lim}(j)$ for this link;

6)   it calculates the value of the total load indicator H for the network, according to the

25   following expression:

$$H = 1 - \frac{1}{N_{cells}} \cdot \min\left\{ \sum_{j=1}^{N_{cells}} \frac{\eta_{lim}(j) - \eta(j)}{\eta_{lim}(j)}, \ \sum_{j=1}^{N_{cells}} \frac{P_{lim}(j) - P(j)}{P_{lim}(j)} \right\}$$

where N_{cells} is the number of cells present in the simulated network;

7)   it calculates the number of users to be

activated $N_{UESTEP}(s)$, for example by using the following expression:

$$N_{UESTEP}(s) = \min \begin{Bmatrix} N_{UEMIN}(s) + (1-H) \cdot [N_{UEMAX}(s) - N_{UEMIN}(s)], \\ N_{UETOT}(s) - N_{UESERV}(s) - N_{UETOT}(s) \end{Bmatrix}$$

The sequence of the values of $N_{UESTEP}(s)$ is calculated
5   in the course of the first event-based micro-simulation and is then stored. In the subsequent event-based micro-simulations, the sequence of values of $N_{UESTEP}(s)$ calculated in the first event-based micro-simulation is retrieved from the store.

10 The RNC_MC object 11 also carries out the further operations of:

-   selecting in a random way, for each service, the UE_MC objects 12, numbering $N_{UESTEP}(s)$, to be activated from the $N_{UETOT}(s)$ UE_MC objects 12 to be activated;

15 -   considering the set of cells belonging to the corresponding "candidate set" for each UE_MC object 12;

-   simulating the admission control procedures and/or algorithms for each of the cells belonging to
20 the "candidate set". For the UMTS standard, these procedures and/or algorithms comprise, for example, the following known checks:

1) a check of the pilot channel reception quality, using the following expression:

25 $$\frac{CPICH\_RSCr_j}{RSSI} \geq Squal\_CPICH$$

where RSSI denotes the total received wideband power in the downlink, while $CPICH\_RSCP_j$ denotes the power received in the CPICH channel. Both of these

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measurements are simulated in the second UE_PHY module 17. by interaction with the RLM object 15. Squal_SCH is a network configuration parameter characteristic of the UE_MC object 12 and is
5 contained in the configuration file 6;

3) a check of the load factor of the uplink, using the following expression:

$$\eta(j) + \Delta\eta < \eta_{lim}(j)$$

where η(j) is the current value of the load factor in
10 the uplink, calculated from the noise increase factor, while η_{lim}(j) is the admission control threshold for the uplink. Both of these parameters are taken from the list of Cell Context objects for the cell j. $\Delta\eta$ represents the load estimate
15 associated with the link requested by the mobile terminal and is a network configuration parameter characteristic of the transport format associated with the UE_MC object 12 for the uplink. If the check yields a negative outcome for the transport format
20 currently assigned to the UE_MC object 12 in question, and if a transport format for the uplink having a lower bit rate than the current one has been defined for the UE_MC object 12 in question, the check of the load factor is repeated with the value
25 $\Delta\eta$ assumed to be that of the transport format having a lower bit rate. The process is iterated until the check yields a positive outcome, or until the transport formats defined for the UE_MC object 12 in question for the uplink have been exhausted.

30 4) check of the power transmitted in the downlink, using the following expression:

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$$P(j) + \Delta P < P_{\text{lim}}(j)$$

where P(j) is the current value of the power transmitted in the downlink by the cell j and $P_{\text{lim}}(j)$ is the admission control threshold for the power of
5 the downlink. Both of these parameters are taken from the list of Cell Context objects for the cell j. Additionally, ΔP represents the power estimate associated with the link requested by the mobile terminal, and is a network configuration parameter
10 characteristic of the transport format associated with the UE_MC object 12 for the downlink. If the check yields a negative outcome for the transport format currently assigned to the UE_MC object 12 in question, and if a transport format for the downlink
15 having a lower bit rate than the current one has been defined for the UE_MC object 12 in question, the check of the load factor is repeated with the value ΔP assumed to be that of the transport format having a lower bit rate. The process is iterated until the
20 check yields a positive outcome, or until the transport formats defined for the UE_MC object 12 in question for the downlink have been exhausted.

5) a check of the number of codes allocated in the downlink, using the following expression:

25 $$N_{COD}(j) + n_{UECOD} < N_{CODMAX}(j)$$

where $N_{COD}(j)$ is the current number of codes allocated in the downlink for the cell j and $N_{CODMAX}(j)$ is the admission control threshold relating to the maximum number of available codes. Both of these parameters
30 are taken from the list of Cell Context objects for the cell j. Additionally, n_{UECOD} represents the number

of codes requested by the service associated with the link requested by the UE_MC object 12 in question. n_{UECOD} is a network configuration parameter characteristic of the transport format associated

5 with the UE_MC object 12 for the downlink. If the check yields a negative outcome for the transport format currently assigned to the UE_MC object 12 in question, and if a transport format for the downlink having a lower bit rate than the current one has been

10 defined for the UE_MC object 12 in question, the check of the load factor is repeated with the value n_{UECOD} assumed to be that of the transport format having a lower bit rate. The process is iterated until the check yields a positive outcome, or until

15 the transport formats defined for the UE_MC object 12 in question for the downlink have been exhausted.

The cells for which all the checks listed above have had a positive outcome, for one of the transport formats in question, are considered by the RNC_MC

20 object 11 to be in macrodiversity mode with the UE_MC object 12 in question. The set of cells in macrodiversity mode is denoted by the term "active set".

The cells for which at least one of the checks listed

25 above has yielded a negative outcome, for all transport formats in question, are not included by the RNC_MC object 11 in the active set of UE_MC objects 12 in question. In this case, for each of these cells, the RNC_MC object 11 inserts into the

30 list of blocked links 47 a reference to the UE_MC object 12 in question, together with a code which identifies the check (or set of checks) whose outcome

was negative.

Also during the step of processing an admission
control event 103, the RNC_MC object 11 carries out
the further operation of sending messages to the
5 NodeB_MC objects 13 and the UE_MC objects 12 in such
a way as to create a dedicated channel in the uplink
between a transmitter 18 of the UE_MC object 12 and a
receiver 24 of the NodeB_MC object 13, for each of
the cells considered to be in macrodiversity mode,
10 and a dedicated channel in the downlink between a
receiver 19 of the UE_MC object 12 and a transmitter
23 of the NodeB_MC object 13, for each of the cells
considered to be in macrodiversity mode.

The UE_MC objects 12 for which the checks have been
15 carried out and which have at least one cell in each
of their active sets are considered by the RNC_MC
object 11 to be active terminal mobiles. A reference
to these objects is inserted by the RNC_MC object 11
into the list of active mobile terminals 60. The
20 RNC_MC object 11 also inserts a reference to the
UE_MC objects 12 considered to be active in each of
the lists of reference to active mobile terminals
contained in the lists of Cell Context objects
relating to the cells in macrodiversity mode with the
25 UE_MC objects 12 considered to be active.

The UE_MC object 12 for which the checks have been
carried out and which have no cells in their active
sets are considered by the RNC_MC object 11 to be
terminals out of service; a reference to these
30 objects is inserted by the RNC_MC object 11 into the
list of mobile terminals out of service 26, and is
associated with the cause "blocked by admission

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control".

The first step of processing a power control event 104 comprises, according to the invention, the following operations carried out by the UE_MC object 5   12:

-    simulating the procedures of signal/noise ratio measurement carried out by the corresponding receiver, by interaction with the RLM object 11, for both the uplink and the downlink;·

10 -   sending a power control command, based on the measurements made, to all the transmitters connected in macrodiversity mode to the receiver in question.

Specifically, two types of power control command are defined:

15 a)   an UP command, sent when the measured signal/noise ratio is lower than the target signal/noise ratio, defined for the transport format associated with the link in question;

b)   a DOWN command, sent when the measured 20 signal/noise ratio is higher than the target signal/noise ratio defined for the transport format associated with the link in question. Each transmitter therefore receives one or more power control commands from the receivers linked to it. On 25 the basis of these commands it varies the transmission power associated with each link, according to the following method found in the UMTS specifications:

a)   if it receives at least one DOWN command, it 30 decreases the transmission power by a value equal to

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the step defined for the transport format associated
with the link in question. If the transmitted power
value, after application of the reduction, is lower
than the minimum value specified for the link in
5 question, the transmitted power is set to the minimum
value, calculated by subtracting the value of the
dynamics of the transmitter in question (the mobile
terminal end or Node B end) from the maximum value
specified for the transmitter;

10 b)   if all of the commands it receives are of the UP
type, it increases the transmission power by a value
equal to the step defined for the transport format
associated with the link in question.

If a non-zero value of the power control command
15 processing delay is specified for the transport
format associated with the link in question, the
power variation is not carried out during the current
power control event: the command sent by the receiver
is stored and processed in one of the following power
20 control events, selected according to the value of
the processing delay.

For each link, each transmitter also stores, in a
known type of vector associated with the transmitter,
the values of transmitted power relating to the most
25 recent power control events. The number of values to
be stored is set by means of the configuration file
6.

In the first step of checking the power convergence
condition 105, each transmitter calculates the
30 maximum (Pmax) and the minimum (Pmin) of the power
values stored in the vector associated with the

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transmitter. Each transmitter then calculates the difference between said maximum and minimum values and compares it with the amplitude of a convergence window set by means of the configuration file 6. If

5   this difference is less than the amplitude of the convergence window, the convergence condition for the link in question is achieved. In this situation, the transmitter sends a message to the RNC_MC object 11.

The RNC_MC object 11 monitors, for both the uplink

10 and the downlink, the number of messages received at the end of each first step of checking the power control convergence condition 105. If the number of messages received is greater for each of the two links than a threshold determined in percentage terms

15 with respect to the total number of active transmitters for the link in question, and set by means of the configuration file 6, the RNC_MC object 11 inserts into the queue of events a power control event which the simulation engine 10 proceeds to

20 execute, interrupting the sequence of power control events. Otherwise, the simulation engine 10 causes the execution of a new power control event (first step 104).

In the step of processing a congestion control event

25 106, the RNC_MC object 11 simulates the congestion control procedures and/or algorithms. For the UMTS standard, for example, the RNC_MC object 11 carries out the following operations:

-       a check of the load factor in the uplink:

30 $\eta(j) + \Delta\eta' < \eta_{\lim}(j)$

where $\eta(j)$ is the current value of the load factor in

the uplink, calculated from the noise increase factor, while $\eta'_{lim}(j)$ is the congestion control threshold, relative to the load, for the uplink. Both of these parameters are taken from the list of Cell

5 Context objects for the cell j;

- a check of the power transmitted in the downlink:

$$P(j) < P'_{lim}(j)$$

where P(j) is the current value of the power

10 transmitted in the downlink by the cell j, while $P'_{lim}(j)$ is the congestion control threshold, relative to the power, in the downlink. Both of these parameters are taken from the list of Cell Context objects for the cell j.

15 If at least one of the two checks yields a negative outcome, this means that the cell j in question is in overload conditions. In this case, the RNC_MC object 11 selects a group of UE_MC objects 12, including active ones, belonging to the service class with less

20 stringent requirements, and sends them a message which informs them of the congestion situation, with details of the critical link in terms of the congestion (the uplink, the downlink or both). The content of the group, in other words the number of

25 mobile terminals which make it up, is set by the configuration file 6. When each UE_MC object 12 receives the message informing it of the congestion, it attempts to select a transport format having a lower bit rate than that of the critical link: if

30 this transport format is available, it selects it as the new transport format for the link in all the

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cells belonging to its active set; otherwise the
UE_MC object 12 removes the congested cell from its
active set.

In this case, the RNC_MC object 11 inserts into the
5   list of blocked links 47 a reference to the blocked
    link, together with a code which identifies the link
    which has given rise to the congestion. If the UE_MC
    object 12 in question has no other cells in its
    active set, it enters the out-of-service condition.
10 In this situation, the RNC_MC object 11 inserts a
    reference to this mobile terminal into the list of
    mobile terminals out of service 26 with which it
    associates the cause "blocking due to congestion
    control". The mobile terminal is then removed from
15 the list of active mobile terminals 60.

The second step of processing a power control event
107 and the second step of checking the power
convergence condition 108 are entirely similar to the
first steps 104 and 105 described previously. In
20 particular, if the second step of checking the power
convergence condition 108 has a positive outcome, in
other words if convergence is achieved, the RNC_MC
object 11 inserts into the queue of events an outage
control event which the simulation engine 10 proceeds
25 to execute, interrupting the sequence of power
control events. If the opposite is true (negative
outcome), the simulation engine 10 causes the
execution of the second step 107.

In the step of processing an outage control event
30 109, the RNC_MC object 11 sends to all the active
UE_MC objects 12 (in other words those having active
sets) a message which triggers, for each UE_MC object

12, the outage control procedures and/or algorithms
specified by the UMTS standard. For the UMTS
standard, these procedures and/or algorithms require
each UE_MC object 12 to carry out the following
5 operations:

- a check that the difference in dB between the
maximum power associated with the UE_MC object 12 in
question and the power transmitted in the uplink is
greater than a given threshold, set by means of the
10 configuration file 6;

- a check that the difference in dB between the
signal/noise ratio in the downlink and the target
signal/noise ratio specified for the requested
service is either positive or negative, but smaller
15 in absolute terms than a given threshold, set by
means of the configuration file 6.

If at least one of the two checks yields a negative
outcome, the UE_MC object 12 attempts to select a
transport format having a lower bit rate, in respect
20 of outage, than that of the critical link: if this
transport format is available, it selects it as the
new transport format for all the cells belonging to
its active set; otherwise it enters the out-of-
service condition.

25 In this case, the RNC_MC object 11 inserts into the
list of mobile terminals out of service 26 a
reference to this mobile terminal, associating it
with the cause "blocking due to outage control". The
mobile terminal is then removed from the list of
30 active mobile terminals 60.

The third step of processing a power control event

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110 and the third step of checking the power
convergence condition 111 are entirely similar to the
first steps 104 and 105. In particular, if the third
step of checking the power convergence condition 111

5 has a positive outcome, in other words if convergence
is achieved, the RNC_MC object 11 inserts into the
queue of events an event of collecting and processing
the statistical results 112, which the simulation
engine 10 proceeds to execute, interrupting the

10 sequence of power control events.

If the opposite is true (negative outcome), the
simulation engine 10 causes a new execution of the
third step 110.

In the step of collecting and processing the

15 statistical results 112, the RNC_MC object 11 sends
to all the simulation objects a message which starts
the collection of the statistical results. For each
type of simulated value, a dedicated statistics
processing module is defined, as indicated by the

20 reference number 8a in Figure 1, and proceeds to
collect the statistical results associated with said
value.

The statistical results associated with a value can,
for example, consist of the mean, the median, the

25 variance, the standard deviation, the probability
distribution and the cumulative distribution.

In detail, each simulation object (including the
RNC_MC object 11) sends to the data processing
modules 8a the statistical results 113 relating to

30 simulated values which are particularly significant
for the object. For example, the UE_MC objects 12

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send statistical results 113 for the following values: the transmission power in the uplink, the signal/noise ratio in the downlink, the bit rate of the uplink, the bit rate of the downlink, the value 5 of the Ec/Io parameter of the pilot channel CPICH (which expresses the signal/noise ratio for the pilot channel CPICH), and the current size of the corresponding active set. The NodeB_MC objects 13 send, for each cell associated with them, statistical 10 results 113 for the following values: total transmitted power in the downlink, load factor for the uplink, inter-cell interference factor for the uplink, and transmitted power for each downlink. The RNC_MC object 11 send statistical results 113 for the 15 following values: number of mobile terminals blocked by admission control in the course of the simulation, number of mobile terminals blocked by congestion control in the course of the simulation, number of mobile terminals blocked by outage control in the 20 course of the simulation, and signal/noise ratio for each uplink.

The data processing modules 8a receive the statistical results 113 for the various simulated values, and use these to calculate an indicator of 25 accuracy for each value. The accuracy indicators can be defined, for example, in terms of confidence intervals associated with the statistical results or with a subset of the results, according to known methods such as those described in J.P.C. Leijen, 30 Statistical Techniques in Simulation, Dekker 1974. The size of the confidence intervals is defined in the configuration file 6. The accuracy indicators can

also be defined, for example, as indicators of
stability of the statistical data. For example, a
stability indicator δX can be defined for the mean of
a value X at the end of the micro-simulation based on
5 n events, according to the following expression:

$$\delta X = E_n\{X\} - E_{n-1}\{X\}$$

where $E_n\{X\}$ denotes the mean of the value X
determined at the end of the simulation n, while $E_{n-1}\{X\}$ denotes the mean of the value X determined at
10 the end of the simulation n-1.

These accuracy indicators are then stored in the
simulation database 8, together with the statistical
data.

Advantageously, the information provided by these
15 accuracy indicators can be used to minimize the
simulation time, while providing full control of the
accuracy and reliability of the results.

In the step of checking the accuracy of the resulting
statistical data 116, the simulation engine 10
20 compares each accuracy indicator obtained in the step
of collecting and processing the statistical results
112 with a corresponding predetermined accuracy
threshold defined in the configuration file 6.

If this accuracy threshold is exceeded, the
25 simulation engine 10 terminals the simulation
algorithm 100 (stop); otherwise the simulation engine
10 causes the execution of a new step of event-based
micro-simulation 102.

Figure 6 shows in a flow diagram an example of the
30 operation of the simulation algorithm according to

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the invention.

In the example in Figure 6, the simulation algorithm 200, according to the invention, comprises a first and a second event-based micro-simulation 201 and 202.

More specifically, the simulation algorithm 200 starts with a step of initialization of the simulation 207.

The simulation algorithm 200 then proceeds with the execution of the first event-based micro-simulation 201 in which, after a step of initialization of the micro-simulation 208, a first admission control event 203 is processed. In the first admission control event 203, the distribution of n1 mobile terminals in the simulation scenario (first traffic scenario) is specified, these terminals corresponding to n1 UE_MC objects 12 and being divided if necessary into groups belonging to different services.

The first event-based micro-simulation 201 then proceeds with the processing of a first power control event, continuing with the check of the power convergence condition and the collection and processing of first statistical results 209 relating to the n1 mobile terminals.

The simulation algorithm 200 then processes a second admission control event 206, in which n2 mobile terminals (second traffic scenario) are distributed in the simulation scenario, corresponding to n2 UE_MC objects 12, divided if necessary into groups belonging to different services. The n2 mobile terminals are added to the n1 mobile terminals

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distributed previously.

The first event-based micro-simulation 201 then
proceeds with the processing of a second power
control event, continuing with the check of the power
5 convergence condition and the collection and
processing of second statistical results 210 relating
to n1+n2 users.

The simulation algorithm 200 then proceeds with the
execution of the second event-based micro-simulation
10 202 which is entirely similar to the first event-
based micro-simulation 201.

Specifically, the second event-based micro-simulation
202 comprises: a step of initialization of the micro-
simulation 211; the processing of a first admission
15 control event 205, in which n1 mobile terminals
(first traffic scenario) are distributed in the
simulation scenario, corresponding to n1 UE_MC
objects 12, divided if necessary into groups
belonging to different services; the processing of a
20 first power control event; the checking of the power
convergence condition; the collection and processing
of first statistical results 212 relating to the n1
users; and the processing of a second admission
control event 206, in which n2 mobile terminals are
25 distributed in the simulation scenario, corresponding
to n2 UE_MC objects 12, divided if necessary into
groups belonging to different services. The n2 mobile
terminals are added to the n1 mobile terminals
distributed previously, thus forming a second traffic
30 scenario consisting of n1+n2 users.

The second event-based micro-simulation 202 then

proceeds with the processing of a second power control event, the checking of the power convergence condition, and the collection and processing of second statistical results 213 relating to n1+n2

5 users.

The simulation algorithm 200 therefore makes it possible to evaluate jointly a first traffic scenario relating to n1 mobile terminals and a second traffic scenario relating to n1+n2 mobile terminals. This

10 result is obtained by providing to separate modules dedicated to the processing of the statistical results relating to n1 and to n1+n2 mobile terminals respectively.

Specifically, a first module, associated with the

15 first traffic scenario, processes jointly the first statistical results 209 made available after the event of collecting the statistical results for the first event-based micro-simulation 201 and the first statistical results 212 made available after the

20 event of collecting the statistical results for the second event-based micro-simulation 202, to obtain performance indicators for the first traffic scenario.

A second module, associated with the second traffic

25 scenario, processes jointly the second statistical results 210 made available after the event of collecting the statistical results for the first event-based micro-simulation 201 and the second statistical results 213 made available after the

30 event of collecting the statistical results for the second event-based micro-simulation 202, to obtain performance indicators for the second traffic

scenario.

The performance indicators for the first and second traffic scenarios are stored in the simulation database 8.

5   The advantages of the method of evaluating the performance of a multi-service mobile telephone network according to the invention are evident from the above description.

In particular, it should be emphasized that the
10 method of evaluation according to the invention makes it possible to simulate the radio resource management procedures and/or algorithms with adequate accuracy and reliability, while minimizing the time required for the simulation.

15 Furthermore, the method of evaluation according to the invention can simulate a plurality of traffic scenarios in a single simulation while providing adequate control of the accuracy and reliability of the results.

20 Finally, the method of evaluation described and illustrated here can clearly be modified and varied in numerous ways, all contained within the scope of the inventive concept as defined in the attached claims.

25 For example, the method of evaluation according to the invention can be applied to multi-service mobile telephone networks based on standards other than the UMTS standard, such as the CDMA 2000 or GSM/EDGE standard. For this purpose, it will be necessary:

30 -   to redefine the simulation objects and the

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corresponding data structures so that they correspond to the network equipment and mobile terminal equipment provided by the system to be simulated;

-    to redefine the evolution of the simulation, in
5 order to model the behavior of the radio resource management algorithms provided by the type of mobile telephone network to be simulated.